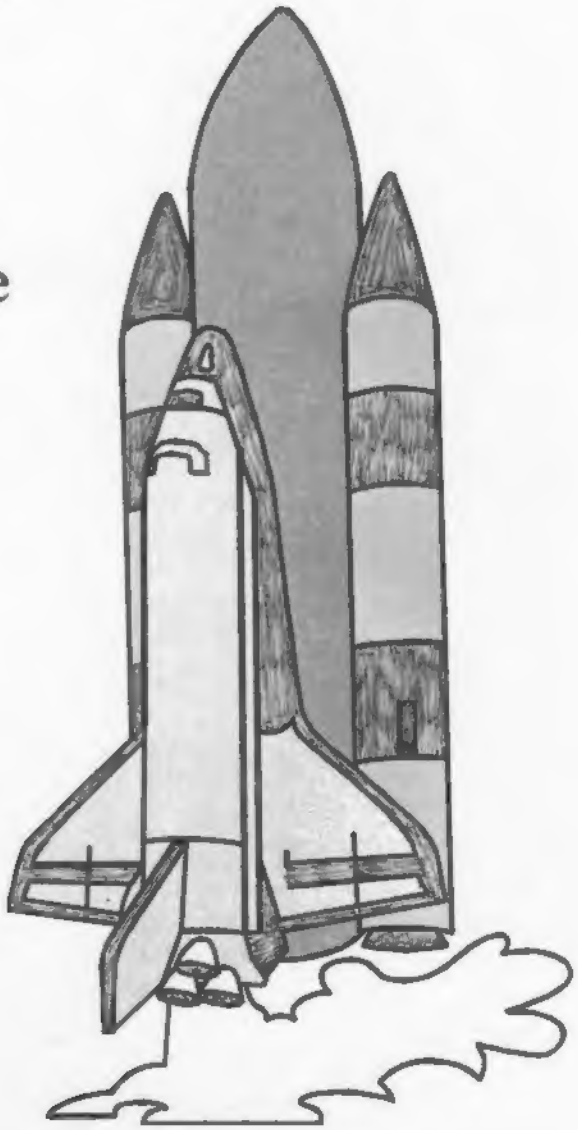
LIQUID NITROGEN HANDLER'S TRAINING

NSTC Course #0314

Employee Training Guide



Presented By The NASA Safety Training Center

July 2007

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LIQUID NITROGEN

1.0 APPEARANCE

High-purity liquid nitrogen is a faintly yellow, transparent liquid, slightly lighter than water. Gaseous nitrogen is colorless, odorless and tasteless. The minimum purity liquid nitrogen is 99.5% with oxygen being the major impurity.

Chemical Nature. Nitrogen in either a gaseous or liquid form is highly inert. It is noncorrosive and will undergo chemical reactions only at very high temperatures. It is nonflammable and does not present a fire hazard.

Solubility. Liquid nitrogen is miscible with liquid oxygen and liquid fluorine at all temperatures. Gaseous nitrogen is only slightly soluble in water.

Stability. Liquid nitrogen is stable to shock, heat and electrical spark.

Table 16-1. Physical Properties of Liquid Nitrogen

Property	English Units	Metric Units
Boiling Point	-320° F	-195.5° C
Freezing Point	-346° F	-215° C
Density, Liquid	50.46 lb/cu ft at -320° F	0.807g/cm^3 at -195.5° C
Specific Gravity-Vapor (Relatives to S.T. P. Air)	0.967	
Critical Density	2.59 lb/gal	0.311g/cm^3
Critical Pressure	493 psia	3.40 x 10^{6}N/m^2
Critical Temperature	-232.5°F	-147°C
Vapor Pressure	20 psia at -316°F	1.38 x 10^{5}N/m^2 -193.3°C
	52 psia at -298°F	3.58 x 10^{5}N/m^2 -183.3°C
	113 psia at -280°F	7.79 x 10^{3}N/m^2 at -173.3°C
	214 pisa at -262°F	1.48 x 10^6 N/m^2 at -163.3°C
Absolute Coefficient of Viscosity (gas at 1 atm)	———	0.01778 centipoises at 25° C
Absolute viscosity at 25°C	———	0.01809 cp. at 20 atm. 0.01916 cp. at 70 atm.
Density, gas	0.0725 lb/cu. ft at 70°F (1 atm.)	1.16 x 10-^{3}g/cm^3 at 21.1°C
N/m^2 = 7.50 x 10^{-3} mm Hg = 9.87 x 10^{-6} std atm.		

2.0 HAZARDS

Health Hazards. Nitrogen leaks in confined areas pose a great threat to personnel. Because it is odorless, tasteless, and imperceptible, the victim is not aware his oxygen supply is insufficient to sustain life. Entry into a suspected or known enriched nitrogen atmosphere (oxygen content less than 19.5%) to do routine work is not permitted, unless standby rescue equipment and trained personnel are provided.

Frostbite. Frostbite or cryogenic "burns" can occur when liquid nitrogen, cold nitrogen vapors, or an uninsulated cryogenic component contacts the skin or eyes. Removal of clothing, water impingement (possibly from a safety shower), or even handling of an injured person can cause further damage to tissue. Transport the injured person to a medical facility for treatment.

First Aid and Self Aid. Never attempt entry rescue of personnel in a confined area unless you are equipped and trained to do so. Obtain medical aid.

Fire Hazards. Pure liquid nitrogen presents no fire hazard. However, avoid contamination with combustible materials or oxidizers, especially oxygen, if the nitrogen is to be used for pressurizing propellant systems

Explosion Hazards. Pure liquid nitrogen presents no chemical explosion hazard. Undetected contamination with combustibles or oxygen could result in a serious explosion if the nitrogen is introduced into a closed system containing substances with which the contaminants react. In transfer operations, liquid nitrogen should not be exposed to air, because oxygen from the atmosphere will condense in the liquid nitrogen. If a vessel of liquid nitrogen becomes contaminated with air, the liquid nitrogen can freeze the water vapor to ice and may plug inlet and outlet lines, including vent and relief ports. This can result in a "locked-up" vessel that may pressurize to pneumatic rupture. Since most pressure instrumentation is located on external stand-off piping which can also be plugged by the contamination, the pressurization could go unnoticed.

Pressure rupture may occur when liquid nitrogen is trapped in a closed system and refrigeration is not maintained. Nitrogen cannot be kept as a liquid if its temperature rises above -232.8^{0} F, regardless of confining pressure. Liquid nitrogen trapped between valves can cause the pipe or tube to rupture violently. Loss of refrigeration can cause a storage tank to rupture if the pressure is not relieved by suitable devices.

3.0 SAFETY MEASURES

Operations involving the handling of more than laboratory amounts of liquid nitrogen should be performed by two or more persons. Self-contained breathing apparatus must be immediately available. Trained supervision of all potentially hazardous activities involving liquid nitrogen shall be provided.

Education of Personnel. The following subjects should be thoroughly explained to all persons working with storage, handling or transfer of liquid nitrogen:

(a) Nature and properties of nitrogen in both liquid and gaseous states, with emphasis on the extremely low temperature of liquid nitrogen and its ability to exert excessively high pressures in closed systems if allowed to warm from normal storage temperatures to near the critical point (-232^{0}F).

(b) Danger of suffocation from the exclusion of oxygen

INERTS - ASPHYXIATION HAZARD

RESPONSE TO OXYGEN DEFICIENT ATMOSPHERE

STAGE	O2 % BY VOLUME	SYMPTOMS
1	12 - 16	Increased breathing and pulse rate Muscular coordination slightly disturbed
2	10 - 14	Consciousness continues. Emotional upsets. Abnormal fatigue upon exertion. Disturbed respiration.
3	6 - 10	Nausea and vomiting. Inability to move freely. Loss of consciousness may occur; victim may collapse and although aware of circumstances be unable to move or cry out.
4	below 6	Convulsive movements. Gasping respiration. Respiration stops, and a few minutes later heart action ceases.

Note that in the above table, there is no sense of alarm or panic in a person suffering from oxygen deficiency.

(c) Compatible construction materials

(d) Proper equipment and its operation

(e) Use and care of personal protective equipment and clothing

(f) Safety measures, self aid and first aid.

Personnel Protection. The principal hazards of liquid nitrogen are the danger of suffocation and burns caused by its extremely low temperature.

Hand and Foot Protection. Because contact with liquid nitrogen or an uninsulated N_2 container may result in frostbite, hand protection shall be worn. The gloves should fit loosely for easy removal if liquid nitrogen runs inside. High-top leather footwear shall be worn to keep liquid nitrogen from getting inside. Trouser legs shall be cuffless and should be worn outside the shoe tops.

Head, Face, and Body Protection. Handlers of liquid nitrogen should protect head and face by wearing acid-type goggles and a face shield, mask or hood, that will stop splashes coming from any direction. An apron of approved material shall be worn if liquid nitrogen is being handled in an open system. If it is spilled on clothing of absorbent material such as wool, it will remain in contact with the body and cause burns. Therefore, a limited protection suit of non-absorbent material must be worn where gross spillage or splashing is possible.

Respiratory Protection. Respiratory protection shall be worn in unventilated areas where liquid or gaseous nitrogen is handled, except where only small quantities are involved. Canister-type masks are totally ineffective for protection against asphyxiation by nitrogen and must not be used.

4.0 MATERIALS AND EQUIPMENT FOR TRANSFER AND STORAGE.

(a) Liquid nitrogen is extremely cold, and **(b)** it is an asphyxiant. It must, therefore, be stored in fixed or mobile containers of approved design, materials and construction and suitably housed.

Materials. When subjected to the temperature extremes of liquid nitrogen service, many materials undergo a marked physical change. The extent of the change for a given material should be known before it is specified for low temperature use. Metals should be able to withstand impact shock at low temperatures, as well as the stresses produced by the extremely low temperature of liquid nitrogen. Their selection will be based primarily on the intended uses, since neither corrosiveness nor reactivity are factors for consideration.

Metals. Ordinary carbon steels and most ferritic and martensitic alloy steels are unsuitable for liquid nitrogen service because they lack ductility at low temperatures. The following metals are satisfactory for this service:

Austenitic chrome-nickel nickel steels
stainless steel, 18-8 series
copper
brass
bronze
nickel steel (9%)
copper -silicon alloys
Monel
aluminum
shredded lead
titanium

Nonmetals. Nonmetal materials must also be selected to withstand low temperatures. The following nonmetals are suitable for this service and may be used singly or in any combination:

(a) Tetrafluoroethylene (TFE Teflon, TFE Halon, or equivalent)

(b) Polycholorotrifluoroethylene (Kel-F, Halon CTF or equivalent)

(c) Selected types of graphite

Lubricants. Materials used in handling liquid nitrogen must be free of grease, oil and other combustible materials. Use special lubricants, such as the fluorolubes, unless aluminum is present.

TRANSFER AND STORAGE EQUIPMENT

Containers and Tanks. Liquid nitrogen may be stored in stationary or mobile tanks of approved materials and construction. Storage tanks should be tested as required by applicable provisions of the ASME Unfired Pressure Vessel code or DOT specifications to ensure against defect in material or fabrication. Materials used for pressure vessels used at temperatures lower than -20°F should be impact-tested in accordance with paragraph UG-84, Section VIII, of the ASME Code.

Containers for shipping, storing and transferring liquid nitrogen may be fabricated in accordance with any standard that meets the structural requirements for thet container. Vacuum-insulated tanks shall be used for storage. The insulated area between the inner and outer shells shall be maintained under vacuum and shall have a pressure-relief device or a rupture disc. The storage tank itself shall be of welded construction; it shall be equipped with a rupture disc and a pressure-relief valve that has an adequate vent line. The vents shall discharge to the atmosphere. Bottom outlets are recommended for storage tanks, as they materially simplify the transfer-system design and the selection of pumping equipment.

Pipes and Fittings. The pipes and fittings shall be of approved materials and construction and shall be hydrostatically tested at specified pressures. The use of welded and flanged connections is recommended when ever possible. Threaded connections are permissible when other methods are not feasible. TFE tape thread sealant is recommended.

Pumps and Hose. Since the storage tanks may be designed with bottom outlets, reciprocating-type or flooded-suction centrifugal pumps may be used when gravity-flow or pressure transfer is not applicable. A graphite-braided Teflon packing is recommended as a pump-shaft seal Hoses shall be of proper design, engineered specifically for liquid nitrogen service.

Pressures Gages. Liquid nitrogen equipment shall be monitored with pressure gages of approved types as required. In order to minimize operator reading errors, all pressure gages used for a common purpose should have identical scales.

Venting Systems and Safety Relief Valves. Storage containers shall be equipped with an adequate vent line and a pressure relief valve. These vents shall discharge to the outdoor atmosphere. All lines and vessels in which liquid nitrogen may be trapped between closed valves shall be equipped with pressure relief valves.

5.0 MAIN STORAGE AND READY STORAGE

Storage, transfer and test areas must be kept neat and free from combustibles. They must be frequently inspected. If provided in the area, use of safety showers to treat cryogenic "burns" is not recommended. When moving large containers of liquid nitrogen, trucks or dollies shall be used to minimize the possibility of spillage.

Handlers must wear approved protective clothing and, in confined areas, respiratory protection. Since nitrogen is a gas at ordinary temperatures and pressure, the primary danger from a spill or leak is the reduction of atmospheric oxygen.

Buildings and Areas. The important factors to consider are the quantity of liquid to be store and the type of storage container

Construction. The storage facility should be well ventilated. Liquid nitrogen storage tanks normally are not covered because of their special vacuum-insulated construction. If coverage for a storage facility is required, any open shed structure of approved materials shall be used.

Diking. Major storage facilities may be surrounded by curbing that will direct the flow of liquid emerging from storage containers, to an open uninhabited area for the evaporation process.

Electrical Equipment. Electrical equipment shall be installed in accordance with the National Electrical Code (reference 5) for the hazard involved.

Access Roads. At least two access roads to transfer and storage sites shall be provided, wide enough at each site to give adequate space for turning.

Safety Equipment. Facilities shall be provided near the storage area for the proper storage of protective clothing and equipment. The operation of safety equipment should be frequently checked. A life support detection and alarm system is recommended for below grade or confined areas containing liquid nitrogen.

Drainage. The storage tank site should be properly drained to prevent damage in other areas.

Ventilation. Wherever liquid nitrogen can evaporate into a confined area, the area should be adequately ventilated to prevent the development of an excessive gaseous nitrogen concentration in the atmosphere. This is especially important because nitrogen gas is odorless and colorless and can cause suffocation without any warning.

Housekeeping. Tanks, piping and equipment used in liquid nitrogen service must be clean and free of grease and oil. Periodic inspections shall be made by supervisory personnel to ensure good housekeeping practices.

Containers

Tanks. Liquid nitrogen must be stored in stationary or mobile tanks of approved materials and construction.

Cylinders. Liquid nitrogen may be stored and shipped in small cylinders or containers of various sizes and shapes, specifications designed to hold low-temperature, liquefied gases and made of materials that can withstand the rapid changes and extreme differences in temperature encountered in working with nitrogen. Containers designed for low temperature liquids are built to withstand normal operating pressures, but all containers should either be open or protected by a vent or other pressure-relieving devices that permit vapors to escape. When a special vented stopper or venting tube is used, as on some small portable containers, the vent shall be checked at regular intervals to ensure that it is not plugged with ice formed from water vapor condensed from the air. Only vent tubes and stoppers supplied with these portable containers shall be used. Inadequate venting can give rise to excessive gas pressure, which can damage or burst a container.

Tanks Trucks. Liquid nitrogen can be transported and stored in specially constructed semi-trailers or trucks of various types and capacities that have double-walled storage tanks. The space between the walls is filled with a specially prepared insulating material; also, the chamber between the two shells is evacuated by a vacuum system to minimize the loss of liquid from heat transfer and evaporation. Tank trucks and semi-trailers may be equipped with liquid nitrogen pumps, necessary valving, instrumentation, pressure relief devices, vacuum pumps and pressuring coils for transferring the chemical by means of gaseous nitrogen pressure. Tank trucks having internal vapor pressure under 25 psig are not now regulated by DOT; when pressure in the tank is 40 psia (25 psig), the tanks must be approved by the DOT and a special permit obtained to use them.

Location of Tanks. All main areas, tanks and containers shall be located convenient to the test facility.

6.0 SYSTEMS AND EQUIPMENT CLEANING

Liquid nitrogen transfer and storage systems should be free of oil, grease and particulate matter. Cleanliness requirements are dependent upon the intended use of liquid nitrogen. All systems, vaporizers, tube storage manifolds, valves, etc., should meet cleanliness requirements established for propellant systems in which nitrogen is being used for pressurization or inerting.

7.0 TRANSFER OPERATIONS

Liquid nitrogen may be transferred by gravity flow, pump or differential pressure. The procedures for equipment operation will be determined by local designs. All operating personnel shall be completely and thoroughly instructed before using the equipment. All valves, pumps, switches, etc., shall be identified and tagged. In developing transfer procedures, the following should be taken into account:

(a) The cryogenic nature of the liquid

(b) The suffocating property of nitrogen

(c) The high vapor pressure of liquid nitrogen at low temperatures of -300^0 to -259^0 F.

(d) Liquid nitrogen will build up pressure in container and transfer equipment unless the vapor is allowed to escape confinement at the proper rate. Filling lines are generally not vacuum insulated and, as long as the liquid flows through them unimpeded, no hazard from pressure build-up due to evaporation can be expected. When valves at the extremities of those lines are closed, however, pressure will increase rapidly unless the liquid is removed from the line. This should be done immediately after the transfer has been completed and before the filling line is disconnected. All lines and vessels in which liquid nitrogen may be trapped between closed valves shall be equipped with pressure-relief valves. As the relief valve may freeze, these lines shall also be equipped with rupture discs. Liquid nitrogen should not be exposed to air while being transferred so that oxygen will not condense into the liquid nitrogen. Handlers must wear approved protective clothing and, in confined areas, respiratory protection. Since nitrogen is a gas at ordinary temperatures and pressures, the primary danger from a spill or leak is the reduction of atmospheric oxygen.

(e) Containers or Cylinders. When liquid nitrogen is being transferred from one container to another, the receiving vessel must be filled as slowly as possible to minimize the thermal shocks that occur when any material is cooled. A predetermined approved procedure shall be used when liquid nitrogen is transferred.

(f) When it is not safe or convenient to tilt the container, use a discharge tube to remove the liquid. Always use a discharge tube to remove liquid from 50 to 100 liter containers.

Tank Cars and Motor Vehicles. Suppliers of liquid nitrogen will furnish loading and unloading instructions as part of their service. The users shall be instructed by the supplier in the proper use of equipment. Always follow all the procedures prescribed by the manufacturer for operating and maintaining equipment used with liquid nitrogen. All personnel working with liquid nitrogen must be properly trained and supervised.

Main Storage Tanks. The equipment and techniques employed in the storage and transfer of liquid nitrogen are usually determined by the requirements of the users. When converting tanks from some other use to nitrogen storage, great care must be exercised to get the tank absolutely clean. Periodic inspections after extended use and after long shutdown periods are advisable.

8.0 TRANSPORTATION

Shipping containers are generally vacuum-insulated tank cars or truck-mounted vacuum-insulated tanks. All tanks shall be fitted with appropriate relief valves, which shall discharge to the atmosphere. Liquid nitrogen tanks holding more than 150 gallons, shipped in closed boxcars or trucks, shall have discharge vents or relief valves to the atmosphere.

Storage and shipping tanks and their insulation shall be made of noncombustible material. If the insulation is contained by an outer metal jacket, the jacket shall have a pressure relief device so that, in case of leakage through the inner container, pressure will not build up and damage the vessel.

The equipment and the technique employed in distributing liquid nitrogen are usually determined by the user's requirements. Potential users shall obtain necessary engineering information and data on construction of the equipment from producers.

Transportation Accident Procedures

In case of spill or leak, move vehicle out of traffic flow.

(a) Attempt to stop leak (if it can be shut off). Determine cause of spillage.

(b) In case of loss of vacuum/insulation in a liquid container, and abnormal pressure rise in the product tank, the entire contents will probably have to be vented to the atmosphere.

In case of catastrophic failure of product tank:

(a) Direct liquid flow away from traffic flow to open area.

(b) Avoid bodily contact with liquid nitrogen.

9.0 EMERGENCY PROCEDURES

Spills, Leaks, and Decontamination. In handling spills or leaks of liquid nitrogen, two factors must be taken into account:

(a) Liquid nitrogen is extremely cold.

(b) Nitrogen gas is an asphyxiant.

Firefighting. Pure liquid nitrogen presents no fire hazard. However, avoid contamination with combustible materials or oxidizers, especially oxygen, if the nitrogen is to be used for pressurizing propellant systems. In emergency situations, liquid nitrogen may be used as a fire-extinguishing agent, since it acts to exclude air or oxygen by forming an inert gas blanket that will dissipate rapidly.

First Aid and Self Aid. Never attempt to rescue personnel in confined areas unless equipped and authorized. Whenever possible, immediately remove the victim to fresh air. Obtain medical aid.

10.0 DISPOSAL

Small Quantities. Vent to the atmosphere.

Large Quantities

(a) Allow the liquid to evaporate in an open area away from traffic, water mains, and sewer systems.

(b) Do no confine liquid.

SELECTED TEXT FROM OSHA HEALTH GUIDELINES FOR NITROGEN

The complete document can be found at:

http;//www.osha-slc.gov/SLTC/healthguidelines/nitrogen/recognition.html

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR NITROGEN

Disclaimer: These guidelines were developed under contract using generally accepted secondary sources. The protocol used by the contractor for surveying these data sources was developed by the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), and the Department of Energy (DOE). The information contained in these guidelines is intended for reference purposes only. None of the agencies have conducted a comprehensive check of the information and data contained in these sources. It provides a summary of information about chemicals that workers may be exposed to in their workplaces. The secondary sources used for supplements III and IV were published before 1992 and 1993, respectively, and for the remainder of the guidelines the secondary sources used were published before September 1996. This information may be superseded by new developments in the field of industrial hygiene. Therefore readers are advised to determine whether new information is available.

INTRODUCTION

This guideline summarizes pertinent information about nitrogen for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine whether new information is available.

HEALTH HAZARD INFORMATION

1. Acute exposure: The signs and symptoms of overexposure to nitrogen may include nausea, drowsiness, blue coloration of the skin and lips, unconsciousness, and death

PERSONAL HYGIENE PROCEDURES

If liquid nitrogen contacts the skin, workers should flush the affected areas immediately with plenty of tepid water to reduce the freezing of tissue. Do not apply direct heat or rub frozen areas.

Clothing contaminated with liquid nitrogen should be removed immediately.

STORAGE

Compressed nitrogen should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's Hazard Communication Standard

[29 CFR 1910.1200]. Containers of nitrogen should be protected from physical damage and heat and should be stored separately from ozone.

SPILLS AND LEAKS

In the event of a leak or spill involving nitrogen gas or liquid nitrogen, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak:

1. Stop the leak if it is possible to do so without risk.

2. Notify safety personnel of major spills or leaks.

3. Evacuate all personnel until ventilation can restore oxygen concentrations to safe levels.

4. Emergency personnel need self-contained breathing equipment.

5. Allow the spilled nitrogen to evaporate.

RESPIRATORY PROTECTION

* Conditions for respirator use

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Air supply respirators must be worn if the ambient concentration of nitrogen is high enough to cause an oxygen-deficient atmosphere. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should only use respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

* Respiratory protection program

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's Respiratory Protection Standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a

knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the latest edition of the NIOSH Respirator Decision Logic [NIOSH 1987b] and the NIOSH Guide to Industrial Respiratory Protection [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Workers should use appropriate personal protective clothing and equipment that must be carefully selected, used, and maintained to be effective in preventing skin contact with liquid nitrogen. The selection of the appropriate personal protective equipment (PPE) (e.g., gloves, sleeves, encapsulating suits) should be based on the extent of the worker's potential exposure to liquid nitrogen. There are no published reports on the resistance of various materials to permeation by liquid nitrogen.

To evaluate the use of various PPE materials with liquid nitrogen, users should consult the best available performance data and manufacturers' recommendations. Significant differences have been demonstrated in the chemical resistance of generically similar PPE materials (e.g., butyl) produced by different manufacturers. In addition, the chemical resistance of a mixture may be significantly different from that of any of its neat components.

Any chemical-resistant clothing that is used should be periodically evaluated to determine its effectiveness in preventing dermal contact. Safety showers and eye wash stations should be located close to operations that involve liquid nitrogen.

Splash-proof chemical safety goggles or face shields (20 to 30 cm long, minimum) should be worn during any operation in which a solvent, caustic, or other toxic substance may be splashed into the eyes.

In addition to the possible need for wearing protective outer apparel (e.g., aprons, encapsulating suits), workers should wear work uniforms, coveralls, or similar full-body coverings that are laundered each day. Employers should provide lockers or other closed areas to store work and street clothing separately. Employers should collect work clothing at the end of each work shift and provide for its laundering. Laundry personnel should be informed about the potential hazards of handling contaminated clothing and instructed about measures to minimize their health risk.

Protective clothing should be kept free of oil and grease and should be inspected and maintained regularly to preserve its effectiveness.

Protective clothing may interfere with the body's heat dissipation, especially during hot weather or during work in hot or poorly ventilated work environments.

SELECTED TEXT FROM:

NASA Procedures and Guidelines (NPG: 8715. Draft 2)

The complete document can be found at:

http;//www.hq.nasa.gov/office/codeq/doctree/doctree.htm

NASA Procedures and Guidelines

NPG: 8715.Draft 2
Effective Date:

NASA SAFETY MANUAL PROCEDURES AND GUIDELINES

Responsible Office: QS/Safety and Risk Management Division

CHAPTER 4: SAFETY TRAINING AND PERSONNEL CERTIFICATION

4.5. PLANNING AND IMPLEMENTATION

4.5.1. Safety Training Program.

A comprehensive safety training program will be formulated by each Center. The following should be considered in developing the safety training program for all employees:

4.5.1.1. Management commitment to establish and implement comprehensive safety training programs (ideally, this should be in the form of a policy statement issued by senior management).

4.5.1.2. Recognition of OSHA, NASA, National Fire Protection Association (NFPA), Federal Aviation Administration (FAA), Environmental Protection Agency (EPA), and other training requirements.

4.5.1.3. Identification of employee training groups within the Center population and determination of present training levels.

4.5.1.4. Identification of specific tasks, hazardous conditions, or specialized processes and equipment encountered by employees that would require safety training, e.g., certification training, cryogenic liquid carrier driver or hazardous waste operations, etc.

4.5.1.5. Identification and documentation of the planned training to be given to each employee category and the intended approach (course, literature, etc.). Refer to Appendix B for a suggested sample training schedule and career development plan.

4.5.1.6. Determination of the availability of safety training resources. A lack of a specific training resource will require the development of specialized training course materials.

4.5.1.7. Establishment of a training schedule.

4.5.1.8. Review, evaluation, and revision, if necessary.

4.5.2. Documentation.

The Center Safety Office will maintain a current copy of the Center Safety Training Plan.

CHAPTER 6: OPERATIONAL SAFETY

6.5. PROTECTIVE CLOTHING AND EQUIPMENT

6.5.4. Examples of PCE.

Items which may be purchased and issued by NASA include, but are not limited to, the following:

6.5.4.1. Safety goggles and safety spectacles (plain and prescription).

6.5.4.2. Welding helmets and shields.

6.5.4.3. Safety shoes.

6.5.4.4. Steel sole and/or toe safety boots.

6.5.4.5. Aprons, suits, and gloves (e.g., fire resistant materials, leather, rubber, cotton, and synthetics).

6.5.4.6. Protective head gear (e.g., hard hats and caps, liners, helmets, and hoods).

6.5.4.7. Barricades, traffic cones, flags, scaffolds, warning signs, alarms, lights, shields, and other public protective devices.

6.5.4.8. Face shields.

6.5.4.9. Specialty items of protective nature (e.g., **cryogenic handlers** suits, scape suits, fire fighter suits, foul weather gear, harnesses, life belts, lifelines, life nets, insulated clothing for "cold test" exposure, supplied air suits, and electrical protective devices).

6.5.4.10. Concentration alarms, toxic gas indicators, explosive gas indicators.

6.5.5. Health Related PCE.

Guidance for purchasing respiratory protective devices and other health-related PCE shall be issued by the NASA Occupational Health Office.

SELECTED TEXT FROM:

JSC REQUIREMENTS HANDBOOK FOR SAFETY, HEALTH, AND PROTECTION (JPG 1700.1H)

CHAPTER 305,
Working Safely with Cryogenic Fluids

The complete document can be found at:

http;//www4.jsc.nasa.gov/safety/index.htm

Chapter 305

Working safely with cryogenic fluids

This could be you . . .

Two technicians passed out while transferring liquid nitrogen from a truck because nitrogen spilled into the loading dock and displaced oxygen in the area. They were rescued and are okay.

A liquid helium dewar ruptured. Fortunately, no one was in the room at the time.

A liquid nitrogen dewar exploded and sent glass fragments flying. Fortunately, the technicians working with the dewar were not in the path of the flying glass.

1. Who must follow this chapter?

You must follow this chapter if you:

a. Use, handle, store, or transfer cryogenic fluids as a part of your job.
b. Supervise anyone who does the above tasks.

2. What does this chapter cover?

This chapter covers the minimum requirements to handle and use common cryogenic fluids safely. You'll find emergency treatment information in Attachment 305A, Appendix 3B.

3. What is a cryogenic fluid?

A cryogenic fluid is a liquid with a normal boiling point below -238° F (221° R, -150° C, 123° K). Commonly used cryogenic fluids include the following:

a. Liquid helium – LHe (normal boiling point - 452° F)
b. Liquid hydrogen – LH2 (normal boiling point - 423° F)
c. Liquid nitrogen – LN2 (normal boiling point - 320° F)
d. Liquid oxygen – LO2 (normal boiling point - 297° F)
e. Liquid air – LAir (normal boiling point - 318° F)
f. Liquid argon – LAr (normal boiling point - 303° F)

Fluorine, neon, carbon monoxide, methane, nitric oxide, krypton can be liquefied and are cryogenic fluids, but are rarely used at JSC in the liquid state.

4. What hazards do cryogenic fluids pose?

Cryogenic fluids could cause any of the following safety problems:

a. Cryogenic burns from the extreme cold, eye damage from cold vapors.
b. Skin stuck to cold surfaces.
c. Overpressurization and rupture of a pressure system or vessel-when cryogenic fluids try to vaporize due to heating from the surroundings, they can increase the pressure 700 to 1000 times.
d. Asphyxiation.
e. Upper respiratory irritation from breathing cold vapors.
f. Fire and explosion.

Requirements for all cryogenic fluids

5. What precautions must I observe when I work with any cryogenic fluids?

If you handle any cryogenic fluids, you must observe these precautions:

a. Do tasks involving cryogenic fluids with two or more people except for laboratory use from a small close container.
b. Deactivate systems with proper energy controls found in Chapter 502, "Lockout/tagout practices," of this handbook before you start any maintenance or repair work.
c. Vent cryogenic systems through appropriate valves. Release gases so that the wind or room ventilation will direct them away from people.
d. If you need to put warm objects in cryogenic fluids, do it slowly and use tongs to insert or remove the objects.
e. If you need to put a cryogenic fluid into a warm container, do it slowly to minimize boiling and splashing.
f. Keep unprotected body parts away from the cold surfaces of pipes or vessels that contain cryogenic fluids.
g. Leave frost that forms on uninsulated surfaces undisturbed to help prevent liquid air (liquid nitrogen plus liquid oxygen) from accumulating.
h. Do a hazard analysis for any area where cryogenic fluids are used or stored.
i. Make sure you have a procedure or hazardous operations permit as described in Chapter 109, "Hazardous operations: safe practices and certification," of this handbook.

6. Where may I work with cryogenic fluids?

Any work you do with cryogenic fluids must be:

a. Near safety and firefighting equipment that you properly maintain.
b. Away from combustibles.
c. Away from unprotected or unauthorized personnel.
d. Within 25 feet of eyewash stations and emergency showers.

e. In well-ventilated areas. Use oxygen analyzers and alarms to monitor for low oxygen concentrations if you are working with LHe, LH2, LN2, or LAr. Use oxygen analyzers and alarms to monitor for high oxygen concentrations if you are working with LO2.

7. Where may I store cryogenic fluids?

Locations where cryogenic fluids are stored must follow these requirements:

a. Store cryogenic fluids outside or in large, open, and well-ventilated rooms that are vented to the outside. Use oxygen analyzers and alarms as described in Subparagraph 6.e above.
b. Continuously ventilate any area where inert cryogenic fluids are used, even at night and on weekends, unless you remove them from the area. Leave air handlers or exhaust ventilation on at all times.
c. Label the entrance to any area with inert cryogenic fluids to alert personnel that asphyxiation is possible in that area due to oxygen-displacing cryogenics.

8. What action must I take in case of a skin burn from a cryogenic fluid?

Before doing any tasks involving cryogenic fluids make sure you have Attachment 305A, Appendix 3B readily available. It covers how to treat skin burns from a cryogenic fluid. An injured person needs immediate professional medical help.

9. What precautions must I observe when storing, using, or transferring cryogenic fluids?

If you transfer, use, or store any cryogenic fluids, you must observe these precautions:

a. Transfer liquid slowly to reduce thermal shock to containers.
b. Don't breathe cryogenic vapors.
c. Don't allow ice to accumulate on a neck or near the vent of a cryogenic vessel. Ice could plug the vent and cause the vessel to rupture.
d. Empty and purge any cryogenic vessel with ice accumulating on the outer surface and either dispose of it or take it out of service for repair. The ice indicates a poor vacuum in the annular space resulting in poor insulation.
e. Tape or cage exposed portions of glass containers to minimize flying glass if the glass breaks.
f. Follow these requirements to prevent sparks or arcs:
    - Ground all stationary hydrogen and oxygen equipment.
    - Bond mobile and stationary equipment used to transfer and receive liquid air, oxygen, and hydrogen and make sure that all equipment involved in the transfer shares a common ground.

- Purge all condensable gases from liquid hydrogen transfer hoses in service with helium gas. Transfer liquid hydrogen only with specially designed equipment.

Requirements for certain cryogenic fluids

10. What precautions must I observe when handling liquid nitrogen?

As a gas, nitrogen is colorless, odorless, tasteless, non-toxic, and almost totally inert as described in Attachment 305E, Appendix 3B. The main health hazard of nitrogen is asphyxiation. Nitrogen can displace oxygen in the air in enclosed or semi-enclosed areas. If you use or handle liquid nitrogen, you must observe these precautions:

a. Don't enter a tank, sump, or closed space that has contained liquid nitrogen until you have purged the space and stabilized the oxygen concentration at normal levels. To enter an oxygen-deficient space, you must wear an air-supplying breathing apparatus. The Occupational Safety and Quality Assurance Branch must approve the entry.
b. Isolate the liquid nitrogen source using a minimum of two positive blocks, such as valves, between the source and the system or equipment. The Occupational Safety and Quality Assurance Branch must approve any other arrangement.
c. If you use valves to block a system, chain or lock them to prevent accidental opening and tag them with DO NOT OPERATE tags. See Chapter 502 of this handbook for detailed requirements on lockout/tagout.
d. If you use an open bleed valve to prevent nitrogen pressurization, chain or lock it open to prevent pressure buildup between blocks or flanges and vent it to outside the work area. e.Use blank or blind flanges as necessary. If the system contains no bleed valves, install a bleed valve on each flange.

17. What training must I have to work with cryogenic fluids?

You must be certified to handle cryogenic fluids as described in Chapter 109 of this handbook. Your training must cover the following subjects for each cryogenic material you work with:

a. Nature and properties of the cryogenic fluid in both liquid and gaseous states.
b. Correct personal protective equipment to use in specific environments and where you can find it.
c. Approved materials that are compatible with the cryogenic fluid.
d. Proper use and care of protective clothing and equipment.
e. First aid procedures.

f. Emergency procedures for handling situations such as leaks, spills, and fires.
g. Good housekeeping practices.

18. What design requirements must cryogenic areas and systems meet?

In addition to the standards listed in Paragraph 19 below, systems handling cryogenic fluids must meet these requirements:

a. Insulate cryogenic vessels and lines or provide drip pans under exposed pipes.
b. Insulate or vacuum jacket cryogenic containers.
c. Provide frangible (burst) discs or other pressure relief devices between the inner vessels and outer tank shell so that pressure rupture cannot occur.
d. Provide safety showers and eyewashes within 25 feet of the work area.
e. Provide enough continuous ventilation and hazardous gas monitors where accidental releases or spills could occur.

19. What other requirements must I follow while handling cryogenic fluids?

In addition to the requirements in this chapter, you must follow these standards as they apply to the work you do. Chapter numbers are for chapters in this handbook.

For . . .	Follow this standard . . .
Certifying employees to work with cryogenic liquids	Chapter 109 of this handbook
Designing cryogenic systems	JHB 1710.13B, "Design, Inspection, and Certification of Pressure Vessels and Pressurized Systems
Finding more data on cryogenic fluids	Attachment 305A & 305E, Appendix 3B

Attachment 305A

Emergency treatment

Recommended emergency treatment for cold-contact burn until medical assistance is available:

- Remove any clothing that may restrict the circulation to the frozen area.
- Do not rub frozen tissue as damage may result.
- As soon as practical, place the affected part of the body in a warm-water bath.
- Never use dry heat to warm a cold-contact burn.
- The victim should be in a warm room if possible.
- If exposure is massive, body temperature will drop and total immersion in a warm water bath will be necessary. Don't warm rapidly. Thawing may require from 15 to 60 minutes and should be continued until the pale blue tint of the skin becomes pink or red.
- Warm drinks and food may be administered to a conscious victim.
- DON'T give alcoholic beverages or allow an injured person to smoke since both decrease the blood flow to the frozen tissues.

NOTE: A cold-contact burn victim requires immediate professional medical treatment. The injured person will be transported immediately to the nearest professional medical facility.

Attachment 305E

Liquid nitrogen (LN_2)

Properties and Characteristics:

- Normal Boiling Point: -320°F (77 degrees Kelvin)
- Appearance: colorless, odorless
- Toxicity: non-toxic to humans
- Vapor Density: .288 lb/ft 3 (about one-fourth that of air)

Material Incompatibility: non-corrosive

Flammability: non-combustible

Safety and Handling:

- Avoid contact with eyes and skin.
- Use proper storage and handling equipment.
- Provide adequate ventilation.
- Obtain a thorough knowledge of this material before handling.
- Use the "buddy" system when handling.

Major Hazards:

- Fire: LN_2 is inert and will not burn.
- Exposure: Vapor is not toxic, but breathing may cause sudden unconsciousness because of lack of oxygen. Cold gas or liquid may cause skin and eye injuries similar to burns (frostbite).

Precautions:

In case of . . .	*Take these actions . . .*
Spill or Leak	Keep unnecessary personnel away. Appropriate personnel required. Use appropriate self-contained breathing apparatus in spill area. Fog in form of condensed moisture usually indicates vapor area. Shut off leak source(s) of supply using proper equipment.
Fire	Nitrogen can help put out fire. Spray tank with water if it is exposed to fire.
Exposure	Remove victim(s) to fresh air. If not breathing, apply artificial respiration and oxygen. Thaw frosted areas with water. Get medical attention promptly.

SELECTED TEXT FROM:

JSC REQUIREMENTS HANDBOOK FOR SAFETY, HEALTH, AND PROTECTION (JPG 1700.1H)

CHAPTER 109,
Hazardous Operations: Safe Practices and Certifications

The complete document can be found at:

http;//www4.jsc.nasa.gov/safety/index.htm

Chapter 109

Hazardous operations: safe practices and certification

This could be you . . .

An employee who wasn't a certified crane operator tried to move an overhead crane. The crane hit a light fixture, caused a short, tripped the breakers and caused the lights to go out.

Another employee who wasn't a certified crane operator tried to move another overhead crane. The crane hit a support frame and was damaged.

Contaminated solder was used in a Space Shuttle component because there were no requirements to certify solder technicians.

1. Who must follow this chapter?

You must follow this chapter if you do or oversee any hazardous operations at JSC or JSC field sites. Paragraph 17 lists the responsibilities of supervisors, line managers, safety representatives, certified confined space supervisors, contracting officers, the Occupational Safety and Quality Assurance Branch, the Medical Operations Branch, and the Employee Development Branch.

2. What is a hazardous operation?

A hazardous operation is a job that involves hazardous materials, conditions, or equipment that could result in injury or property damage if you don't follow special precautions.

Requirements for hazardous operations

3. What requirements must I follow for any hazardous operation?

If you do or oversee hazardous operations, you must:

a. Decide which category¾ I, II, III, or IV¾ your operation belongs in. See Paragraphs 4, 5, 6, and 7 of this chapter.

b. Inform your organizational director of the risks involved in any new or non-routine hazardous operation with the potential for death, serious injury, or loss of critical high dollar value hardware before you start.

c. Make sure, as a supervisor, that everyone follows any requirements that apply to the operation or that are listed on the permit.

d. Use the "buddy system" with at least one standby person in one of these ways:
   - One of you does the job and the other watches from the immediate area of the job to make sure the "worker" is safe.
   - Two of you do the job and you keep in constant contact with a standby person either electronically, mechanically, or visually. The standby person must remain in the immediate area where you are working.
   - Two of you do the job and you keep in contact with a standby person by coded lifeline signals and may be out of sight of the standby person. The responsible safety representative will decide how many worker and standby person combinations there must be.

e. Take extra care, as a supervisor, to recognize and respond to dangerous situations when:
   - Your employees work in hazardous areas they aren't normally assigned to.
   - Your employees are working near public access areas.

5. What requirements must I follow for category II hazardous operations?

Category II jobs involve operations that, if not done correctly, could create a severe hazard to the operator or user, other personnel, or property.

The requirements for category II jobs are similar to those for category I jobs. You may reduce the levels of physical examination, training, and testing because of the lower hazard levels. Your organization must determine the certification and recertification requirements with the concurrence of the Occupational Safety and Quality Assurance Branch or the Medical Operations Branch.

Category II jobs include, but are not limited to, those listed in this table. Chapter numbers given are for chapters in this handbook.

For these personnel or operations . . .	Permit reqd ?	Physio trng reqd ?	Med. exam reqd ?	Follow requirements in . . .
Handling cryogenics	HOP*	no	no	Chapter 305

* HOP - Hazardous operations permit

7. What requirements must I follow for category IV hazardous operations?

Category IV operations require a hazardous operations permit unless you have a procedure as descnbed in Paragraph 11 of this chapter. Medical exams are only required for certain operations. See Chapter 104 for more information on medical exams.

Category IV jobs include, but are not limited to, those listed in this table. Chapter numbers given are for chapters in this handbook.

For these personnel or operations . . .	Follow requirements in . . .
Transferring, transporting, using, disposing of, or otherwise exposing personnel to cryogenic substances, explosives, radiation, etiological agents, flammable or combustible liquids or solids, propellants, poisons, corrosive or oxidizing materials, or compressed gases	Chapter 201 Chapter 305 Chapter 601

Permits and procedures

10. How do I get a permit for hazardous operations?

You must have a permit for certain hazardous operations before you may begin work. Fill out the permit form and post the completed permit at the job site until the job is over. Some operations, such as welding in a confined space, require two or more permits. Permits are only good for a limited time, such as one shift, and expire on the date and time shown on the permit. You must have one of the following permits as required and post it at the job site along with any procedures you will use:

c. A hazardous operations permit for other operations as required by Paragraphs 4 and 5 of this chapter. Use JSC Form 8, "Hazardous Operations Permit," Appendix A. The flowchart in Figure 109-2 describes the steps necessary to complete and approve a hazardous operations permit.

11. Are there any exceptions to permit requirements?

You don't need a hazardous operations permit if you write a detailed procedure and have it approved by the Occupational Safety and Quality Assurance Branch. Confined space entry and hot work permits are always required. To use a procedure, you must:

a. Include the title and telephone extension of each person who would normally receive a copy of the permit with the procedure.
b. Contact those you listed under Subparagraph a above to let them know about your work, before you start.
c. Post a copy of the procedure at the job site as you would post a permit.
d. Send any revisions to the procedure to Occupational Safety and Quality Assurance Branch for review and approval.
e. Review and update the procedures at least yearly.

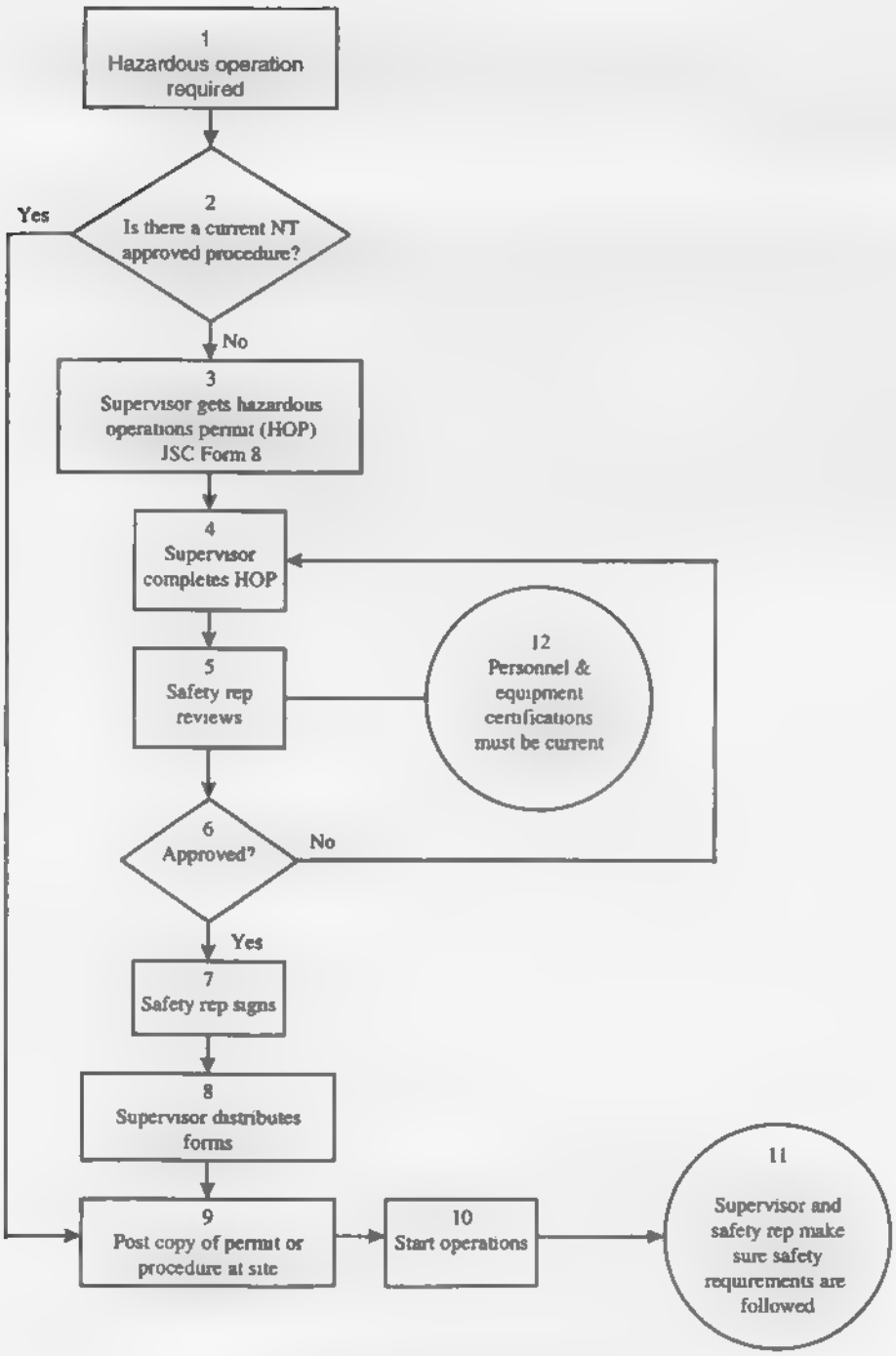

Figure 109-2. hazardous operations permit flowchart.

Certification for hazardous operations

12. How do I become certified to do hazardous operations?

To be certified, you must show that you have the necessary knowledge, skills, judgment, and physical ability to do the job safely. JSC will provide and document your training and certification. Certification must follow these requirements:

a. You must be certified by your management after you:
   - Complete the necessary formal or on-the-job training. Your management must at least outline the on-the-job training you must have and state the minimum number of hours required
   - Pass an oral test, written test, or experience review
   - Get a certification card when the certification examiner determines that you have the required safety knowledge and skills. The certification examiner and certifying officer must both sign the card. You may use JSC Form 353, Appendix A. See NHB 1700.1 (V1-B), Chapter 4, "Safety Training and Personnel Certification," for more information

b. Your organization must keep a record of your certification on JSC Form 209, "Application and Record of Qualification for Personnel Certification," Appendix A, or a similar form.

c. Certification examiners:
   - Must know the requirements of the operation they will certify.
   - Should be at least one organizational level higher than the employee to be certified.
   - Must be appointed by the Center Director or his or her designated representative to certify category I operations.
   - Must be appointed by directorate level official or representative from the organization responsible for the operations to certify category II or III operations

d. Certification is good for 3 years or less if necessary. The certifying officer and your management may request that you be recertified or retested:
   - Any time they question your knowledge or skills.
   - When you have to do any new hazardous operation.

e. You must have a physical examination when required by Paragraphs 4 or 5 of this chapter or by the Medical Operations Branch to be certified or recertified.

LLIS Database Entry: 0254

Lesson Info

- **Lesson Number**: 0254
- **Lesson Date**: 20-aug-1993
- **Submitting Organization**: LERC
- **Submitted by**: S. Papell

Subject/Title/Topic(s):

Liquified Gas Dewars

A five liter, glass lined, liquefied gas dewar exploded after workers completed a transfer of **liquid nitrogen** from it. The explosion propelled fragmented glass from both ends of the dewar. Fortunately, no one was in the path of the razor sharp fragments and no injury resulted. The dewar had been in use for only two years and no physical deterioration had been noted.

Lesson(s) Learned:

Glass lined dewars which are used to transport liquefied gases can explode unexpectedly and endanger personnel in the area.

Recommendation(s):

Wear protective equipment such as faceshield/goggles, cryogenic gloves, long sleeves and an apron when handling cryogenic fluids.

Evidence of Recurrence Control Effectiveness:

N/A

Approval Info:

- **Approval Date**: 15-jun-1994
- **Approval Name**: Maria Havenhill
- **Approval Organization**: LERC/EBAS
- **Approval Phone Number**: 216-977-1483

LLIS Database Entry: 0353

Lesson Info

- **Lesson Number**: 0353
- **Lesson Date**: 09-dec-1994
- **Submitting Organization**: JPL
- **Submitted by**: R.F. Collins

Subject/Title/Topic(s):

Facility Failure During Testing of the Galileo Near Infrared Mapping Spectrometer (NIMS)

Description of Driving Event:

During a recalibration test of the Galileo NIMS flight instrument in a subsystem vacuum chamber, a facility failure occurred. A **liquid nitrogen** supply line fitting separated, causing **liquid nitrogen** to spray on the outside of the chamber, and filling the room with fog. After the break was repaired and in preparation to restart the test, four additional failures occurred, one of which caused the flight instrument to be subjected to a temperature below its qualification limits.

These failures can be attributed to substandard **liquid nitrogen** plumbing, a known idiosyncrasy in a control circuit and human error.

Before the flight instrument was permitted to be tested in the subsystem facility, the required safety certification process had been accomplished and a flight projects office waiver had been requested and approved. The reason for requesting to test in a facility other than the JPL environmental test lab was so as not to introduce unknowns into the recalibration process.

Additional Keyword(s): Science Instruments

Lesson(s) Learned:

Environmental test chambers are subject to several hazards not familiar to most practicing engineers and technicians. Cryogenics, vacuum systems, and thermal control systems all have serious potential safety risks if wrong materials, parts, or assembly techniques are used. Once incorporated, these improper elements may perform well for indefinite periods before bursting, leaking, or otherwise failing. They look ok, they work ok, but they aren't ok.

Recommendation(s):

1. Subsystem facilities must be critically examined for the probability of any failure modes which may subject flight hardware to out-of-specification environments. Specification limits should be alarmed separately from control system limits. Operator response to alarms should be covered by straightforward safing procedures.
2. The proposed use of nonstandard facilities for flight hardware should be very carefully weighed during the planning phase of a project or task and the following should be considered:
    a. Safety certification isn't a foolproof process.
    b. Availability of qualified operators is a greater problem for small subsystem teams than for the officially prescribed environmental test lab, particularly if long-term tests are planned.
    c. Upgrading facilities to meet requirements that are imposed because of the testing of flight hardware is likely to be expensive in schedule and dollars.
    d. Damage and subsequent repair to flight instruments or subsystems is costly in both schedule and dollars and could have severe project and mission impact.

Evidence of Recurrence Control Effectiveness:

N/A

Approval Info:

- **Approval Date:** 14-dec-1994
- **Approval Name:** Carol Dumain
- **Approval Organization:** 125-204
- **Approval Phone Number:** 818-354-8242

LLIS Database Entry: 0550

Lesson Info

- **Lesson Number**: 0550
- **Lesson Date**: 07-may-1997
- **Submitting Organization**: JSC
- **Submitted by**: L. H. Underwood

Subject/Title/Topic(s):

Oxygen-Deficient Atmospheres

Description of Driving Event:

Two technicians were transferring **liquid nitrogen** from a vendor tanker to a tank trailer. Near the end of the operation, visibility was severely limited due to fog caused by venting nitrogen, leading to a decision to shut down the operation until the visibility improved. While shutting down the transfer operation, the technicians became unconscious due to lack of oxygen but recovered with no ill effects after being rescued by the tanker drivers. Technicians were wearing PPE for protection against frostbite, spills, etc., but did not include equipment to detect lowered oxygen levels or to supply breathing air.

At JSC there are a large number of nitrogen containers. The areas surrounding the larger, permanent containers do not normally present pockets in which to trap nitrogen; however, on still days there could be oxygen-deficient areas near the connection the vent, or the 90% fill valve. The smaller portable containers (dewars) could be located in potentially confined areas, also presenting the potential for an oxygen-deficient atmosphere.

Lesson(s) Learned:

Cryogenics are capable of displacing air, resulting in unbreathable, Oxygen-deficient atmospheres.

Recommendation(s):

1. Follow your organization's procedures for handling of cryogenics.
2. Operations with liquid nitrogen should only be performed using the buddy system and by experienced and qualified personnel familiar with the hazards and safety precautions.
3. Resist the urge to rush in and rescue a downed co-worker; 60% of the confined space fatalities happen to the would-be rescuer. If rescue is necessary, use proper protective/breathing equipment.
4. Confined Space Entry requirements and procedures must be followed when working with nitrogen in areas that are not well ventilated.
5. Improve visibility through the use of portable ventilation fans to disperse the vapor cloud surrounding the operation with necessary.
6. Consider use of portable oxygen monitors when working around cryogenic fluids.

Evidence of Recurrence Control Effectiveness:

Safe Alert 1995 SA95013; NASA-JSC Mishap Report 950045

Approval Info:

- **Approval Date:** 14-may-1997
- **Approval Name:** Ronald A. Montague
- **Approval Organization:** NA3
- **Approval Phone Number:** 281-483-8576

LLIS Database Entry: 0580

Lesson Info

- **Lesson Number**: 0580
- **Lesson Date**: 12-jan-1998
- **Submitting Organization**: JSC
- **Submitted by**: Sean Keprta

Subject/Title/Topic(s):

Adherence to Manufacturer's Recommendations and to Established Procedures for Hazardous Operations (Plastic Cryogenic Tissue Storage Vial Burst Hazard)

Description of Driving Event:

A small plastic vial stored in **liquid nitrogen** burst while laboratory workers were inventorying and transferring vials from one dewar to another. During the transfer a vial burst, causing superficial cuts on the hands of two laboratory workers.

The vial manufacturer had updated catalog and shipping documents to alert customers that the vials were not recommended for storage in the liquid phase of cyrogenically stored nitrogen. Instead, the manufacturer recommends that the vials be stored only in the gaseous phase of cryogenic nitrogen. The seal on the vials is not adequate to protect against seepage of liquid into the vial which could then burst following removal from the liquid unless adequate precautions were taken to allow the liquid to evaporate and escape slowly.

Workers were not wearing the selected PPE at the time of the mishap. The PPE had been removed because it was too bulky to permit manipulation of the small vials. This directly exposed the personnel to low temperature hazards as well as the burst hazard from the cryogen stored vials.

Lesson(s) Learned:

1. Read and implement manufacturer's warnings on products.
2. PPE must be worn when required and must fit the tasks to be performed.
3. Periodic reviews of hazard analyses are capable of revealing any inconsistencies between planned operations and manufacturer's recommendations, protective safeguards, etc., prior to commencement of operations.

Recommendation(s):

Hazard analyses be performed and updated, periodic safety reviews be conducted with all personnel working in the area, and standard operating procedures be checked against the warnings (including updates) provided by equipment vendors. Manufacturers tend to update warnings in their literature, both in catalog and on the data sheet shipped with the equipment when they discover hazards not previously known; such literature needs to be reviewed systematically for such new information. Identify and use suitable protective equipment to allow handling small cryogenic vials that might burst when removed from storage.

Evidence of Recurrence Control Effectiveness:

N/A

Approval Info:

- **Approval Date**: 16-jan-1998
- **Approval Name**: Ronald A. Montague
- **Approval Organization**: NA3
- **Approval Phone Number**: 281-483-8576

JSC Safety Alert

Liquid Argon Dewar Gas Release

What Happened

Recently, a cryogenic dewar filled with liquid Argon released its contents in a materials testing laboratory in Building 15. Displacement of the air by Argon in an unventilated closed room or confined space could result in serious injury or death.

Outcome of the Investigation

The following circumstances can lead to dewar failure and loss of contents.

Damage to the inner vessel (vacuum jacketed or insulated).
Overfilling the dewar beyond its rated liquid capacity.
Improper valve configuration (pressure building valve left open) or leaking valves.
Relief system failure.

What You Can Do

Devise a checklist to be used each time you accept a dewar from a vendor. The checklist should be specific to your use conditions, because different cyrogens and dewars have different storage and use requirements. Some examples for an Argon checklist are: no condensation or frost visible on the dewar, dewar not filled above storage capacity, pressure relief valves in current certification, and so on. Reject the dewar if it does not meet your acceptance specifications. Use your own checklist if you fill a dewar from a bulk cryogen storage area at JSC.

A facility's location and its configuration are critical considerations in avoiding the development of a potentially hazardous atmosphere in the event of dewar failure and loss of contents. Requirements for facility configuration are found in the **JSC Requirements Handbook for Safety, Health, and Environmental Protection, JPG 1700.1, Chapter 305, "Cryogenic liquids and gases: how to work with them safely."** The following requirements for storage of dewars are found in JPG 1700.1:

Perform a hazard analysis for any area where you may use or store cryogens and other hazardous or toxic gases. While gases are lighter than air, others are heavier, and this requires different control configurations.

Locate the dewar outdoors, if possible. If not, locate it in a wide open area (preferably continuously vented). Vent any relief valve to the outside.

If the options above are not possible due to facility limitations, you must have continuous ventilation (general or exhaust) and oxygen analyzers with an audible alarm.

Last Validated: 10/04/99
Last Updated: 10/04/1999 07:23:26
Curator: R. Borremans
Alternate: D. L. Reed
Responsible NASA Official: S. T. Nakamura

JSC Safety Alert

Oxygen-Deficient Atmospheres

What Happened:

NASA has had multiple fatalies because of oxygn-deficient atmospheres. Recent incidents have surfaced indicating the need to reinforce JSC's policy on the handling of cryogens.

Outcome of the Investigation:

JSC has a large number of nitrogen containers. The areas surrounding the larger, permanent containers do not normally present pockets in which to trap nitrogen; however, on still days there could be oxygen-deficient areas near the connection the vent, or the 90% fill valve. The smaller portable containers (dewars) could be located in potientially confined areas, also presenting the potiental for an oxygen-deficient atmoshpere.

What you can do:

Follow your organization's procedures and JHB1700D, "JSC Safety Manual," regarding the storage and handling of cyrogenics.

Operations with liquid nitrogen should only be performed using the buddy system and by experienced and qualifed personnel familiar with the hazards and safety precautions.
Resist the urge to rush in and rescue a downed co-worker; 60% of the confined space fatalities happen to the would-be rescuer.
confined Space Entry requirements and procedures must be followed when working with nitrogen in areas that are not well ventilated.
Improve visibility through the use of portable ventilation fans to disperse the vapor cloud surrounding the operation with necessary.

Regulation(s):

JHB 1700D, Section II, Chapter 2, "Confined Space Entry," Chapter 4, "Cryogenics Materials."

Nitrogen is a colorles, odorless, gas that can displace the oxygen in a confined or semi-confined area resulting in an oxygen-deficient atmosphere. proper procedures must be followed during operations with nitrogen to avoid creating a hazardous atmosphere.

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Curator: R. Borremans
Alternate: D. L. Reed
Responsible NASA Official: S. T. Nakamura